CRACKING THE COMMERCIAL CODE
The SCI Institute Moves Its Collaborative Magic To The Marketplace
by Kimball Thomson
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Chris Johnson is perhaps one of the lowest-profile global research leaders in Utah. Few in Johnson's adopted home state are yet familiar with him or with the Scientific Computing and Imaging (SCI) Institute, the University of Utah-based research organization he founded in 1992 and continues to direct.

The SCI Institute is a multi-disciplinary group of leading-edge researchers and practitioners dedicated to developing knowledge and dynamic imaging/visual simulation tools used in a variety of research and industry applications. The Institute's commercial applications target two industries in particular: medical applications and orientations--medical imaging, surgical planning and medical device design; and computational engineering--such as oil and gas reservoir simulations, combustion, and models and simulations for manufacturing plants.

The Institute began when Johnson joined the faculty of the University's School of Computing (until 2000, the Department of Computer Science). Since then, SCI has grown from an embryonic research group consisting of Johnson and a small cadre of graduate students to a dynamic environment that engages over 50 faculty, staff and students within the University and has close collaborative ties to numerous world-class institutions within and outside the U.S.

"We're often better known and more highly appreciated outside of our own back yard," said Johnson. "I give many invited talks world-wide at universities and other venues, but a lot of people in the state-- even within the University--don't know as much about SCI as people outside do."

Johnson has been prominently on the radar screen of leading organizations outside Utah for a number of years. The raft of awards he has received include:

- 1992: a Young Investigator's Award from the National Institutes of Health (NIH)
- 1994: a National Young Investigator Award from the National Science Foundation (NSF)
- 1995: the NSF Presidential Faculty Fellow Award, from then-President Bill Clinton
- 1996: a Computational Science Award from the Department of Energy (DOE).

Over the past several years, Johnson and SCI have begun to receive increasing recognition inside Utah. In 1996, the Institute was named a Utah Center of Excellence, a designation that was renewed every year until 2000, when SCI had received the maximum allowable Centers funding of $500,000. In 1997, Johnson received both the Par Excellence Award from the University of Utah Alumni Association and the University's Presidential Teaching Scholar Award. Then in 1999, Governor Leavitt awarded him the Governor's Medal for Science and Technology.

Still, SCI's story is not widely known in Utah, especially among people and organizations who could aid the Institute's development. "We need to do a better job getting the word out about the great things going on here," he said, "especially to the state legislature and leaders in Utah's private sector." He notes that his September 2000 Gould Distinguished Lecture at the University of Utah and his January 2001 presentation at a Utah Information Technology Association (UITA) luncheon were "our first opportunities to meet many of these people, and probably the first time most of them had ever heard of the Institute."

If the Institute is able to successfully communicate its message, "SCIRun"--as the Institute's novel scientific computing toolkit was dubbed several years ago by SCI faculty member Steve Parker--may become as closely associated with scientific computing and imaging as the slopes of Big and Little Cottonwood Canyons and Park City are with snow skiing.

COLLABORATIVE LEADERSHIP

One of SCI's hallmarks is its emphasis on collaboration: within the computer science discipline, between academic departments within and outside of the University of Utah, and increasingly, between academia and industry.

The Institute engages researchers and practitioners from such disparate disciplines as chemistry, computing, engineering, mathematics, neurosurgery, physics and radiology, in addition to three dedicated research centers: the Cardiovascular Research and Training Institute, the Center for Advanced Medical Technologies, and the Energy Geosciences Institute. All of the Institute's six principal investigators are faculty members at the University of Utah, some with appointments in multiple departments.

Outside the University, SCI has established 21 strategic research partnerships in the United States and Europe. Stateside partners include the California Institute of Technology (CalTech), Harvard Medical School, the University of Chicago, MIT, and five national laboratories (Argonne, Berkeley, Livermore, Los Alamos and Sandia). European partners include the University of Erlangen, Imperial College London, the University of Leeds, University College London, and the Max Planck Institute for Computer Science.

A VALUE PROPOSITION WITH A PRICE TAG

One prominent East Coast researcher sees the development of SCI in a place such as Utah, outside the traditional corridors of research power, as a natural by-product of the expanding influence of the Internet. "I'm not as surprised as I would have been ten years ago to see a world class research group like SCI--one that is clearly pushing the field of imaging and visual simulation in new and powerful directions--develop in Utah," said Greg McRae, professor of chemical engineering at MIT. "Trade and exchange is getting more intense and active over the Internet, so in a sense it doesn't matter as much as it used to where you set up operations."

McRae, an international authority on environmental emissions and a frequent industry consultant on operational and environmental efficiencies, is currently working with SCI on a project to optimize efficiency and minimize industrial waste for an East Coast chemical plant.

"Increasingly we see pockets of excellence springing up in regions outside the traditional research powerhouses," he continued. "The key is for those regions to recognize what they have in organizations such as SCI, and to give them the support they need to flourish, so they aren't forced to relocate to places that will devote more resources and attention to their development."

McRae's analysis is prescient. Already Johnson has rejected offers from a number of prominent academic research institutions on the West Coast. "I am committed to making SCI flourish here in Utah, if at all possible," said Johnson. "We have built something here, and I would like to see it go to the next level at the University of Utah."

Johnson concedes some frustration, however, that Utah has not expressed the same level of commitment or funding to emerging technologies as have some other states, notably California. "California has been able to take advantage of reciprocal relationships wherein the state government

and industry understand the value of academic technology research. As a result, you have these multiple $100 million state-funded research institutes, doubled or tripled by matching funds from industry. I would love to see that model duplicated here--even proportionately or in niches, since we don't have the resources they do."

University of Utah Dean of Engineering Gerry Stringfellow (recently elected to the National Academy of Engineering) believes SCI brings tremendous value to the University and to the state. "The magic of SCI is that they apply world-class computer science to problems that are intrinsically interesting and important. This is not an isolated center. SCI does solid research across boundaries and borders."

Stringfellow sees SCI as a key new piece of a longstanding tradition of medical/engineering fusion innovation at the University that includes Dr. Willem J. Kolff, father of the artificial kidney and artificial heart. "For me, medical imaging is perhaps the most exciting work going on now at SCI, because it is attacking problems that are so universally important and easy to grasp. They are manufacturing payload ideas--intellectual properties that can be used in the workplace."

Stringfellow sees SCI as a central part of Utah's viability as a participant in the knowledge economy. "If a poor state like Utah wants to be a rich state, we'd better be part of the knowledge economy. The Governor's 5-8 year plan (to double and triple the number of engineering graduates in Utah) provides much of the raw material to be a magnet for companies outside the state. That is important, but it is also important to do world-leading research like SCI is doing. Universities need to be the main source of new ideas and basic fundamental knowledge that provide much of the fodder for industrial development."

"SCI is a tremendous recruiting tool for the University, helping us successfully compete for the absolute best graduate students and college freshmen in the nation," he said. "These are students who come here instead of to MIT, Harvard, Berkeley or Stanford so they can work with Chris and other world leaders like him. We have freshmen doing significant research. It shows how exciting engineering can be, rather than putting barriers around it. If we invest what we need to in order to fully develop centers like SCI into mature institutions, many of these top people will stay in Utah to be a part of something so special."

The dot-com crash is not the end of the computer industry, Stringfellow insisted. "We are at the beginning of a mind-boggling growth period in technology. Now is the time to invest in technology education to provide the manpower and attract companies to Utah. Groups like SCI deserve special attention and investment. If we are diligent and effective in letting people know what we have here--and at the same time, invest in and build what we have--we will develop into a leader in the knowledge economy."

THE NEW SCIENTIST

Johnson believes that advances in scientific computing, together with collaborative medical and computer science research, is ushering in a period of revolutionary growth in medical imaging and other areas. "We will continue to see the creation of increasingly powerful visualization and integrated analysis tools that will help solve important problems in medical diagnosis and treatment, and in other industries."

The chief bottleneck in this process may be the availability of a "new kind of scientist": thinkers and researchers able to comfortably navigate between the boundaries that traditionally separate academic disciplines and academia from industry, and to draw upon a breadth and depth of cross-disciplinary understanding rarely found in the contemporary research climate.

"I think the SCI Institute is a good example of how multidisciplinary computational engineering and science research can work," said Johnson. "You pull together an interdisciplinary mix of people at the cutting edge of their respective disciplines, who are willing and able to collaborate and take the group beyond the current cutting edge to the next level."

The barriers to conducting such research are formidable. "In the academic world, there are these artificial boundaries we call departments," said Johnson. "A lot of the financial and other controls fall inside these departments, which can make it difficult to take people from multiple disciplines and get them to work together."

One chief province of the academic department system is its set of reward mechanisms, based on tenure, recognition and funding. "Tenure is rewarded in a single department, and if you're doing work that is multidisciplinary it may not be as appreciated because the people in your department may not be able to put a value on it as easily as something they know well."

This disincentive is reinforced in the academic publishing world, a highly prestige- and recognition-driven business. "Every field has its showcase journals or proceedings, which it deems to be of high value," said Johnson. "People in departments might not be aware of the journals of comparable prestige and stature in other fields.

"It's also difficult to secure funding when we're bridging disciplines, such as the sciences and medicine. Federally, we've got the NSF on one hand, and the NIH on the other. The NIH supports medically oriented applications, but they don't necessarily fund programs like computer science; NSF backs fundamental computer science, but they want little to do with medical proposals."

Cross-disciplinary projects often encounter resistance from both sides. "You get feedback saying, 'Well you know, I like this part, but that part's really not in our purview.' To get both agencies to talk simultaneously, you have to essentially please two masters. I think that the federal agencies are starting to see that they should do more of this hybrid inter/multi-disciplinary work, but it's just not easy to do right now."

Another challenge to collaborative research is the academic trend dating to the 19th Century toward reductionism and increasing specialization. "For much of the previous 100 years, science has been reductionist--breaking things down into their component pieces--which is important and necessary," said Johnson. "At the same time, I think it's necessary to take those pieces and put them into a larger whole to tackle complicated real-world problems."

One of the key historical problems associated with hyperspecialization has been the different linguistic and theoretical constructs that have increasingly isolated separate departments. "We speak different languages through the different disciplines," said Johnson. "To do true, useful collaboration, we have to overcome communication barriers and learn about one another's area of specialty."

FAITH

The substantial initial groundwork a researcher must do before being able to do rewarding and valuable work in another discipline is one of the key disincentives to doing cross-disciplinary research. "Oft-times the beginning of a collaboration is not cutting-edge research," said Johnson. "It involves learning the language and the field, and maybe doing some development before getting to the point where you can begin cutting-edge collaborative research projects."

This initial process can sometimes take several years, and requires considerable faith in the project's potential benefit in order to stay with the process. "There is a significant ramp-up time, and a lot of

people drop out of the process before seeing any success. They never get to learn how exciting and fruitful this can actually be, and they are resistant to try again."

Notwithstanding these barriers, Utah has a strong track record for successful collaboration. One current example is a Department of Energy project called C-SAFE (the Center for the Simulation of Accidental Fires and Explosions). SCI faculty member Steve Parker is the software architect for the project, which creates an integrated computing environment for the complex simulations running on thousands of CPUs.

"Many separate departments have to work closely together to make a project a success," said Jones. "It's not obvious that a chemical and fuels engineer would work well together with a computer scientist, who would work with a mechanical engineer, etc., but things have gone very well in the first five years. Dave Pershing (C-SAFE principal investigator and the University's academic VP) has made it possible and interesting for us to all work in collaboration. Dave has been able to pull the groups and the expertise together, tackle this complicated, large scale application, and really make it work."

CRACKING THE COMMERCIAL CODE

SCI is also seeking to streamline the process of translating academic research into technological applications. Since much of the funding of the Institute is directed at scientific research rather than commercial spinoffs, SCI has developed corporate partnerships as a commercialization strategy.

Rather than try to commercialize a general problem solving software system, the Institute intends to rely on these partnerships for access to the codes, software, marketing, and supply channels of the partners. In return, the partner can take advantage of SCI's core strengths in visualization, simulation, and modeling. "We know the problem-solving environment and how to plug things into the program," said Jones. "They know what needs to be plugged in, and what the market wants."

The challenge is getting the program ready for demonstration to prospective partners. "Early on, we had major medical imaging companies looking at our research simulations and saying, 'Great, I'll take that now,'" said Johnson. "But it wasn't a shrink-wrapped product we could hand them; it was just proof of concept development and research level grade codes. We didn't have the resources to translate this into a product they would want. We're much closer now, but there's still a gap between us and commercial critical mass. I strongly believe that we are only a few people, some funding, and a bit more equipment away from full commercialization."

"There's kind of a chicken and egg problem," said SCI associate director Greg Jones. "You want to develop your product to the point where you can show you have something marketable, so that you can get investors interested. And you want investors interested so you can gain access to the funds needed to move your product to something that's marketable. That's the circle we've experienced."

Because SCI is a research institute with a fairly strong funding base (approximately $5 million annually) relative to other academic research, they have been able to hire some full time software engineers and programmers. "We have been able to start a software engineering process here within the Institute that has enabled us to create an academic version of code releasable to the general public," said Johnson. "And the Centers of Excellence has helped us prepare for commercialization. Still, we lack the funding and the bandwidth to be able to take the next step--to make it commercially viable, put the user interfaces on it, and to target it specifically to particular clients."

Several of SCI's strategic partners believe that given the right funding and partnerships, the Institute has everything it needs to achieve commercial success. "A lot of people are doing imaging research," said Steve Stevens, chairman of the Department of Radiology at the University who is working with SCI

on a series of vascular imaging models, including studies of the structure and function of blood vessels. "SCI takes modeling to another level with the quality of their 3-D visualization and their analysis and presentation of data and information."

McRae agreed. SCI's fundamental research focuses on "the speed that matters: the time it takes for the end user to get answers to meaningful problems. Their process drastically reduces the time it takes to set up a problem, and the imaging technology allows the user to quickly run, visualize, solve, and apply the results. SCIRun is ideally suited for solving huge, data-heavy problems."

"SCIRun is the most comprehensive system out there for effectively tying multiple models together," added Dave Swensen, manager of software development for Salt Lake City-based Reaction Engineering International. "In our evaluation of the system modeling options out there, SCIRun has clearly come out the leader."

Johnson envisions a panaceac future, where multi-disciplinary research and collaboration will be the accepted norm--a future in which SCI will fit seamlessly. But that time has not yet arrived. "There's been some movement in that direction. It would be interesting to just flip things on their head and say, 'You know, you automatically do multidisciplinary research, it would be unusual for people to only focus on a very very small area--but we're certainly not there yet."

THE SCI INSTITUTE'S PRINCIPAL INVESTIGATORS

- SCI Director **Chris Johnson** is a professor in the School of Computing and a research associate professor of bioengineering and physics. He directs the SCI-based Center for Bioelectric Field Modeling, Simulation and Visualization and is co-director of the Advanced Visualization Technology Center(AVTC)—a national Department of Energy-sponsored center inside SCI--and the Engineering Scholars Program

- **Charles (Chuck) Hansen** is an associate professor of computer science, associate director of the School of Computing and co-director of the AVTC.

- **Greg Jones**, SCI's associate director, is an adjunct professor of radiology and a liaison for the Institute's commercial applications. He has broad experience in research, industry, and man-agement and an educational background that combines doctoral work in biomedical sciences, post-doctoral studies in radiology and an executive MBA.

- **Rob MacLeod** is a research associate professor of internal medicine, an associate professor of bioengineering, acting co-director of the Nora Eccles Harrison Cardiovascular Research and Training Institute (CVRTI), and co-director for the National Institute of Health's Center for Bioelectric Field Modeling, Simulation, and Visualization within SCI.

- **Steve Parker** is a member of the US Department of Energy's Common Component Architecture Forum, a research assistant professor of computer science, and the software architect for the DOE sponsored Center for the Simulation of Accidental Fires and Explosions.

- **Ross Whitaker** is an assistant professor of computer science and is doing image processing research as a member of a National Library of Medicine program called the "Insight Project. "

A FUTURE BEYOND IMAGINING

Hearing the faculty and administration describe the critical mass and capabilities of the SCI Institute, one gets a pretty clear idea of how this facility is setting the pace and establishing a global reputation

for itself and for high-performance computing, visualization, and simulations technology. But this hardly compares with the potential for ground-breaking discoveries that will emerge from the Institute in the coming years. We asked SCI director Chris Johnson to speculate about some of the innovative technologies we can expect to see in the future:

- **Computational medicine**--integration of data from the study of a person's genetic, biochemical, electrical and physiological makeup (from the molecular to the systemic level), leading to the creation of personalized medical treatments for disease.

- **Simulations of living systems**--application of computer technology to uncover the secrets of living systems not accessible from direct measurement, by connecting and integrating information from multiple sources.

- **Creation of a "virtual computational workbench"**--allowing users not only to design but also to modify real-time simulations interactively within a 3D visualization environment. One use for such a device could be to perform "brain walkthroughs" of a neuro-surgical procedure prior to surgery.

- **Multi-modal biomedical image visualization**--combining electrical and biochemical mea-surements with anatomical data from MRI, CT and other medical imaging methods; and map-ping functions to anatomical locations.

- **Understanding the nature of thought**--studying and representing high-level brain functions under normal and abnormal conditions (seeing how activity in different brain cells and regions changes over time and under different circumstances), which might lead to significant answers about how we learn, how and where memories are formed, and the nature of consciousness.